This algorithm works by assigning membership to each node corresponding to each cluster center on the basis of distance between the cluster center and the node. More the node is near to the cluster center more is its membership towards the particular cluster center clearly; summation of membership of each node should be equal to one. After each iteration membership and cluster center are updated according to the formula

Membership of i^{th} node and j^{th} cluster center $\mu_{ij} = \frac{1}{\sum_{k=1}^{c}\left(d_{ij}|d_{ik}\right)^{(2|m-1)}}$

j^{th} cluster center $V_j = \left(\sum_{i=1}^{n}(\mu_{ij})^m\right)/\left(\sum_{i=1}^{n}(\mu_{ij})^m\right) \forall j = 1,2,\ldots.c$

Where, n – number of nodes

V_j – represents the j^{th} cluster center

m –is the fuzziness index $m \in [1, \infty]$

C- represents the number of cluster center

μ_{ij}- represents the membership of i^{th} node to j^{th} cluster center

d_{ij}- represents the Euclidean distance between i^{th} node and j^{th} cluster center

Main objective of fuzzy c means algorithm is to minimize $J(U, V)$

$$J(U,V) = \sum_{i=1}^{n}\sum_{j=1}^{c}(\mu_{ij})^m \|X_i - V_j\|^2$$

Where $\|X_i - V_j\|$ is the Euclidean distance between i^{th} node and j^{th} cluster center

FCM Algorithm steps

Let X = $\{x_1, x_2, x_3 \ldots, x_n\}$ be the set of nodes and
V = $\{v_1, v_2, v_3 \ldots, v_c\}$ be the set of centers.

1. Randomly select 'c' cluster centers.
2. Calculate the fuzzy membership 'μ_{ij}' using the equation shown above
3. Compute the fuzzy centers 'v_j' using the equation.
4. Repeat step 2) and 3) until the minimum 'J' value is achieved or $\|U^{(k+1)} - U^{(k)}\| < \beta$.

where,

'k' is the iteration step.
'β' is the termination criterion between [0, 1].
'$U = (\mu_{ij})_{n*c}$' is the fuzzy membership matrix.
'J' is the objective function.

The clustering technique in-corporated in CCTS is LEACH (Low Energy Adaptive Clustering Hierarchy)and the FCM. BOTH the clustering technique simultaneously select the cluster head and reselecting it, after that the process as same as explained below and obtain the synchronization. In this algorithm, the network is divided into overlapping clusters and the time synchronization process is divided into intra-cluster time synchronization and inter-cluster time synchronization. The intra-cluster time synchronization. Cluster-heads calculate the average values of the skew compensation parameters of intra-cluster virtual clocks of nodes within their clusters and the average values of intra-cluster virtual clocks of nodes, and then they update the clock compensation parameters of intra-cluster virtual clocks and simultaneously broadcast them to the neighboring nodes. Cluster member nodes receive the messages and update the local intra-cluster virtual clock compensation parameters to achieve the synchronization of intra-cluster virtual clocks. The inter-cluster time synchronization. The cluster-heads exchange their intra-cluster virtual clocks and their clock compensation parameters through gateway nodes. The received messages are given corresponding weights according to the size of each cluster. Then cluster-heads update skew and offset compensation parameters of network virtual clocks in order to achieve the synchronization of network virtual clocks.

3. Performance Evaluation

The perform analyses and simulations on convergence rate, communication traffic in MATLAB. The size of the network is 200 nodes distributed randomly. The network is divided into 4 clusters, the number of clusters distributed randomly.

A. Convergence Rate

Analyze the convergence rate of CCTS and CCTS with FCM clustering. The convergence rate can be calculated by the equation

$$k = \frac{1}{\log(1|\lambda)}$$

Where $\boldsymbol{\lambda}$ satisfies Cheeger's inequality $1 - 2\Phi \leq \boldsymbol{\lambda} \leq 1 - \Phi^2/2$. Where Φ is the conduction coefficient of the Markov chain.

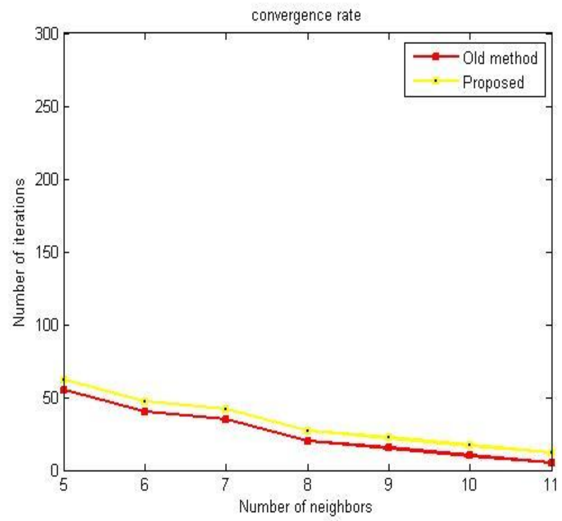

Figure 1: Convergence rate

The figure 1 shows that the convergence rate of networks can be much faster in CCTS with FCM than CCTS when the neighbor numbers of nodes increase.

B. Communication Traffic

In CCTS, the network with M clusters and n nodes needs $1+N_m$ messages within the cluster and n messages for the whole network in the intra-cluster time synchronization. In the inter-cluster time synchronization, the number of messages exchanged between the clusters is $1 + 3|\overline{D_m}|$ and in the whole network is $\sum_{m=1}^{M}(1 + 3|\overline{D_m}|)$. So, in CCTS, the number of messages exchanged in a single-step iteration is $n + \sum_{m=1}^{M}(1 + 3|\overline{D_m}|)$. The comparison of communication traffic between CCTS and CCTS with FCM in a single-step iteration shown in figure 2. It shows the number of messages exchanged in the networks can be much higher in CCTS with FCM than CCTS when the size of network gets larger.

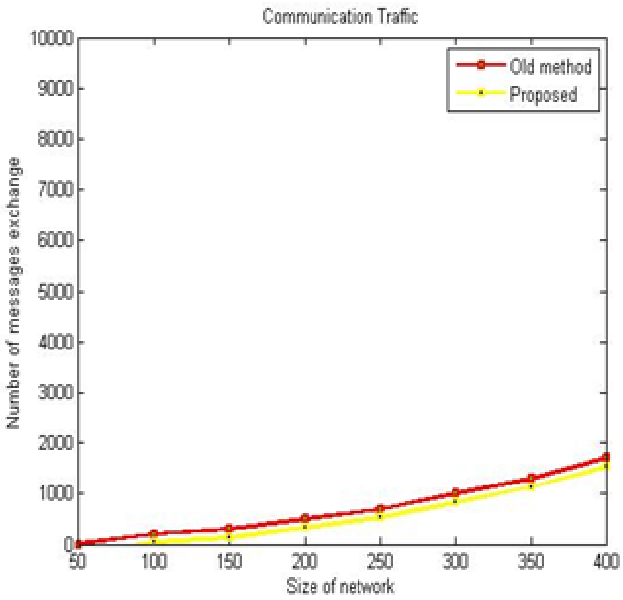

Figure 2: Comparison of communication traffic between CCTS and CCTS with FCM

4. Conclusion

In the existing system LEACH clustering method is used in the algorithm, here accuracy of clustering is less. Fuzzy c means clustering technique is incorporated in the existing method, thus increase the accuracy of the clustering. The clustered consensus time synchronization algorithm with clustering LEACH had good convergence rate but increase traffic in the communication. This new algorithm increases the clustering accuracy and also the convergence rate by incorporating the FCM to the existing system and also reduces the communication traffic than CCTS. Here by incorporating the FCM to the CCTS algorithm thus can increase the clustering accuracy and also the convergence rate and reduce the communication traffic.

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